BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

Sub: **CHE 301** (Heat Transfer)

Full Marks: 210 Time: 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks

SECTION – A

Question 1 is compulsory and carries 45 marks. Answer any **TWO** form the rest.

Heat Transfer Data booklet will be supplied

1. 175, 000 1b/hr of distilled water enters an exchanger at 93°F and leaves at 85°F. The heat will be transferred to 280,000 1b/hr of raw water coming from supply at 75°F and leaving the exchanger at 80°F. A 10 psi pressure drop may be expended on both streams while providing a fouling factor of 0.0005 for distilled water and 0.0015 for raw water when the tube velocity exceeds 6 fps.

   Available for this service is a $15\frac{1}{4}$ in. ID exchanger having $160\frac{3}{4}$ in. OD, 18 BWG tubes 16 ′ 0 ″ long and laid out on $\frac{15}{16}$ in. triangular pitch. The bundle is arranged for two passes, and baffles are speed 12 in. apart. Will the exchanger be suitable?

   Viscosity at caloric temperature for distilled water and raw water are 1.96 and 2.23 1b/ft. hr, respectively. All other fluid parameters can be considered same for both streams. Thermal Conductivity of water at operating condition is 0.36 Btu/hr. ft. °F

   (a) Which fluid would you place in the tube side? explain your reason. **(5)**

   (b) Draw a temperature profile along the heat exchanger length, and find the long mean temperature difference. **(6)**

   (c) Determine the tube side and shell side heat transfer coefficients, h_i and h_o, respectively. **(11)**

   (d) Perform all the necessary calculations and check if the exchanger is suitable for use. **(16)**

   (e) Fill in the attached TEMA sheet and attach it to your answer script. **(7)**

2. It is desired to heat 9820 1b/hr of cold benzene from 80 to 120°F using 6330 1b/hr hot toluene which is cooled from 160 to 100°F. The specific gravities at 68°F are 0.88 and 0.87, respectively. A fouling factor of 0.001 should be provided for each stream. A number of 20-ft hairpins of 2-by $1\frac{1}{4}$ in. IPS pipe are available. How many hairpins are required? **(30)**

3. (a) What is Grashof number? Discuss the implication of this in natural convection system. With a neat sketch show the temperature and velocity profiles on a vertical surface during natural convection. **(12)**

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(b) A metal-clad heating element of 10 mm diameter and of emissivity 0.92 is submerged in a water bath horizontally. If the surface temperature of the metal is 260°C under steady boiling conditions, calculate the power dissipation per unit length for the heater. Assume that water is exposed to atmospheric pressure and is at a uniform temperature. **(18)**

Given:

Latent heat of vaporization of water at atmospheric pressure = 2257 KJ/kg

Water density: 958.4 kg/m^3

Water vapor properties at film temperature:

Density = 4.807 kg/m^3

Heat capacity = 2.56 kJ/kg K

Conductivity = 0.0331 W/m K

Viscosity = 14.85 x 10^{-6} Ns/m^2

4. (a) A cold fluid is heated from 100°F to 275°F by saturated steam at 300°F. Shall they be directed in parallel flow or counterflow? Draw a temperature profile for your preferred orientation. **(10)**

(b) A steam condenser consisting of a square array of 625 horizontal tubes, each 6 mm in diameter, is installed at the exhaust hood of a steam turbine. The tubes are exposed to saturated steam at a pressure of 15 kPa. If the tube surface temperature is maintained at 25°C, calculate **(20)**

(i) The heat transfer coefficient, and

(ii) The rate at which steam is condensed per unit length of the tubes.

At 15 kPa pressure,

Saturation temperature = 54°C

Vapor density = 0.098 kg/m^3

h_{fg} = 2373 kJ/kg

SECTION – B

There are FOUR questions in this section. Answer any THREE.

5. (a) Write short answer of the following questions.

(i) A material that has a high thermal conductivity or a low heat capacity will have a large thermal diffusivity. Justify the statement. **(4x6=24)**

(ii) Why do the glass and glass fiber possess different thermal conductivity? How and why does thermal conductivity change with temperature?

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Contd... Q. No. 5(a)

(iii) Show that the measuring unit of thermal conductivity (k) is w/m°C and that for convection heat transfer co-efficient (h) is w/m^2°C

(iv) The convection heat transfer (h) value for free convection of gases ranges from 2 to 25 w/m^2 °C which is ten times higher for force convection. What is the physical mechanism behind the high values of h for force convection of gases?

(v) What is the mechanism of radiation heat transfer?-State briefly,

(vi) The emissivity (ε) of Black paint (0.98) is is close to the ε of a perfect black body (ε = 1). But why is the emissivity of white paper (ε = 0.97) very close to black paint?-Explain.

(b) A certain superinsulation material having a thermal conductivity of 2 x 10^{-4} w/m°C is used to insulate a tank of liquid nitrogen that is maintained at -196°C; 200 KJ is required to vaporize each kg mass of nitrogen at this temperature. Assuming that the tank is a sphere having an inner diameter (ID) of 0.61m, estimate the amount of nitrogen vaporized per day for an insulation thickness of 2.5 cm and an ambient temperature of 21°C. Assume that the outer temperature of the insulation is 21°C. **(11)**

6. (a) A furnace wall is to be constructed with a 6 cm layer of fire brick (k = 1.0 w/m°C) on the inside. This is covered on the exterior with a layer of block insulation (k = 0.1 w/m°C). The interior of the furnace is at 800°C and the exterior surface is at 70°C. Determine the thickness of block insulation necessary to maintain the firebrick-block insulation interface temperature at 700°C. **(20)**

(b) For a cylinder or wire with internal heat generation the temperature distribution is given by the expression: **(15)**

$$T\text{-}T_w = \frac{q}{4k}(R^2\text{-}r^2)$$

A 5mm diameter wire generates heat uniformly at the rate of 500 MW/m^3. The outside surface temperature of the wire is 150°C, and the thermal conductivity is 20 W/m°C. Calculate the temperature at the center of the wire.

7. (a) A horizontal pipe 20 cm outside diameter carrying steam is in ambient at 32°C. The outside temperature of pipe is 220°C. Calculate the natural convection coefficient and the heat loss per meter length of pipe. Table for properties of air is supplied. The correlation for natural connection: **(17)**

$Nu_f = C(Gr_f.\Pr_f)^m$, $Gr_f = \frac{g\beta(T_w - T_a)D^3}{\gamma^2}$ where $\beta = \frac{1}{T}$ values of 'C' and 'm' for use with the correlation are:

$Gr_f \Pr_f = 10^4\text{-}10^9$, C = 0.53, m = 0.25

$Gr_f \Pr_f = 10^9\text{-}10^{12}$, C = 0.13, m = 0.33

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(b) Describe the thermal boundary layer formation and the hydrodynamic (velocity) layer formation on a heated isothermal flat plate for forced convection heat transfer. **(11)**

(c) Colburn recommended that for forced convection heat transfer in turbulent flow in tubes over a wide range of Prandtl number may be given by the relation:

$St_x \, \mathrm{Pr}^{2/3} = C_{fx}/2$

Show that this relation yields the correlation: **(7)**

$Nu = 0.0395 \, \mathrm{Re}^{3/4} \, \mathrm{Pr}^{1/3}$

Given: $f = 0.316/\mathrm{Re}^{1/4}$; where $C_{fx} = f/4$

8. (a) Hot water at 120°C flows in a stainless steel pipe (k = 15 W/m°C) with inner diameter 1.6 cm and thickness 0.2 cm. The pipe is covered with 0.7 cm thick fiberglass insulation (k=0.038 w/m°C) to ensure that the outer surface of the insulation must not exceed 40°C when the air temperature is 25°C. The heat transfer coefficient inside and outside the pipe are: h_i = 70 W/m^2°C and h_o = 20 W/m^2°C respectively. Determine the rate of heat loss from the pipe. **(25)**

(b) Derive an expression for the overall heat transfer coefficient based on the outside surface area of the inner pipe (U_o) for a double-pipe heat exchanger. Assume that the hot fluid flows in the inner pipe and the cold fluid in the annulus. **(10)**

Relevant Equations

Film condensation for horizontal tube:

$$\overline{h} = 0.725\left[\frac{\rho(\rho-\rho_v)gh_{fg}k_f^3}{\mu_f d(T_g - T_w)}\right]^{1/4}$$

Pool boiling:

$$\dot{q}_{\text{nucleate}} = \mu_l h_{fg}\left[\frac{g(\rho_l-\rho_v)}{\sigma}\right]^{1/2}\left[\frac{C_p(T_s - T_{\text{sat}})}{C_{sf}h_{fg}\text{Pr}_l^n}\right]^3$$

$$\dot{q}_{\text{film}} = C_{\text{film}}\left[\frac{gk_v^3\ \rho_v(\rho_l-\rho_v)[h_{fg}+0.4c_{pv}(T_s-T_{\text{sat}})]}{\mu_v D(T_s-T_{\text{sat}})}\right]^{1/4}(T_s-T_{\text{sat}})$$

$$C_{\text{film}} = \begin{Bmatrix}0.62 \text{ for horizontal cylinders}\\ 0.67 \text{ for spheres}\end{Bmatrix}$$

Values of the coefficient C_{sf} and n for various fluid–surface combinations

Fluid-Heating Surface Combination	C_{sf}	n
Water–copper (polished)	0.0130	1.0
Water–copper (scored)	0.0068	1.0
Water–stainless steel (mechanically polished)	0.0130	1.0
Water–stainless steel (ground and polished)	0.0060	1.0
Water–stainless steel (teflon pitted)	0.0058	1.0
Water–stainless steel (chemically etched)	0.0130	1.0
Water–brass	0.0060	1.0
Water–nickel	0.0060	1.0
Water–platinum	0.0130	1.0
n-Pentane–copper (polished)	0.0154	1.7
n-Pentane–chromium	0.0150	1.7
Benzene–chromium	0.1010	1.7
Ethyl alcohol–chromium	0.0027	1.7
Carbon tetrachloride–copper	0.0130	1.7
Isopropanol–copper	0.0025	1.7

Table for Qs. 07(b)

TABLE A-5
Properties of air at atmospheric pressure†

The values of μ, k, c_p, and Pr are not strongly pressure-dependent and may be used over a fairly wide range of pressures.

T, K	ρ kg/m³	c_p, kJ/kg · °C	$\mu \times 10^5$, kg/m · s	$\nu \times 10^6$, m²/s	k, W/m · °C	$\alpha \times 10^4$, m²/s	Pr
100	3.6010	1.0266	0.6924	1.923	0.009246	0.02501	0.770
150	2.3675	1.0099	1.0283	4.343	0.013735	0.05745	0.753
200	1.7684	1.0061	1.3289	7.490	0.01809	0.10165	0.739
250	1.4128	1.0053	1.5990	11.31	0.02227	0.15675	0.722
300	1.1774	1.0057	1.8462	15.69	0.02624	0.22160	0.708
350	0.9980	1.0090	2.075	20.76	0.03003	0.2983	0.697
400	0.8826	1.0140	2.286	25.90	0.03365	0.3760	0.689
450	0.7833	1.0207	2.484	31.71	0.03707	0.4222	0.683
500	0.7048	1.0295	2.671	37.90	0.04038	0.5564	0.680
550	0.6423	1.0392	2.848	44.34	0.04360	0.6532	0.680
600	0.5879	1.0551	3.018	51.34	0.04659	0.7512	0.680
650	0.5430	1.0635	3.177	58.51	0.04953	0.8578	0.682
700	0.5030	1.0752	3.332	66.25	0.05230	0.9672	0.684
750	0.4709	1.0856	3.481	73.91	0.05509	1.0774	0.686
800	0.4405	1.0978	3.625	82.29	0.05779	1.1951	0.689
850	0.4149	1.1095	3.765	90.75	0.06028	1.3097	0.692
900	0.3925	1.1212	3.899	99.3	0.06279	1.4271	0.696
950	0.3716	1.1321	4.023	108.2	0.06525	1.5510	0.699
1000	0.3524	1.1417	4.152	117.8	0.06752	1.6779	0.702
1100	0.3204	1.160	4.44	138.6	0.0732	1.969	0.704
1200	0.2947	1.179	4.69	159.1	0.0782	2.251	0.707
1300	0.2707	1.197	4.93	182.1	0.0837	2.583	0.705
1400	0.2515	1.214	5.17	205.5	0.0891	2.920	0.705
1500	0.2355	1.230	5.40	229.1	0.0946	3.262	0.705
1600	0.2211	1.248	5.63	254.5	0.100	3.609	0.705
1700	0.2082	1.267	5.85	280.5	0.105	3.977	0.704
1800	0.1970	1.287	6.07	308.1	0.111	4.379	0.704
1900	0.1858	1.309	6.29	338.5	0.117	4.811	0.702
2000	0.1762	1.338	6.50	369.0	0.124	5.260	0.700
2100	0.1682	1.372	6.72	399.6	0.131	5.715	0.707
2200	0.1602	1.419	6.93	432.6	0.139	6.120	0.710
2300	0.1538	1.482	7.14	464.0	0.149	6.540	0.718
2400	0.1458	1.574	7.35	504.0	0.161	7.020	0.730
2500	0.1394	1.688	7.57	543.5	0.175	7.441	

†From *Natl. Bur. Stand. (U.S.) Circ.* 564, 1955.

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TEMA Heat Exchanger Specification Sheet

Company:
Location:
Service of Unit: Our Reference:
Item No.: Your Reference:
Date: Rev No.: Job No.:
Size / in Type Connected in parallel series
Surf/unit(eff.) ft2 Shells/unit Surf/shell (eff.) ft2

PERFORMANCE OF ONE UNIT

		Shell Side		Tube Side	
Fluid allocation					
Fluid name					
Fluid quantity, Total	lb/h				
Vapor (In/Out)	lb/h				
Liquid	lb/h				
Noncondensable	kg/s				
Temperature (In/Out)	F				
Dew / Bubble point	F				
Density	lb/ft3				
Viscosity	cp				
Molecular wt, Vap					
Molecular wt, NC					
Specific heat	BTU/(lb*F)				
Thermal conductivity	BTU/(ft*h*F)				
Latent heat	BTU/lb				
Pressure	psi				
Velocity	ft/s				
Pressure drop, allow./calc.	psi				
Fouling resist. (min)	ft2*h*F/BTU				

Heat exchanged BTU/h MTD corrected F
Transfer rate, Service Dirty Clean BTU/(h*ft2*F)

CONSTRUCTION OF ONE SHELL

Sketch

		Shell Side	Tube Side
Design/Test pressure	psi	/ Code	/ Code
Design temperature	F		
Number passes per shell			
Corrosion allowance	in		
Connections	In	/	/
Size/rating	Out	/	/
in	Intermediate	/	/

Tube No. OD Tks-avg in Length ft Pitch in
Tube type Material Tube pattern
Shell ID OD in Shell cover
Channel or bonnet Channel cover
Tubesheet-stationary Tubesheet-floating
Floating head cover Impingement protection
Baffle-crossing Type single seg Cut(%d) hor Spacing: c/c in
Baffle-long Seal type Inlet in
Supports-tube U-bend Type
Bypass seal Tube-tubesheet joint
Expansion joint Type
RhoV2-Inlet nozzle Bundle entrance Bundle exit lb/(ft*s2)
Gaskets - Shell side Tube Side
Floating head
Code requirements TEMA class
Weight/Shell Filled with water Bundle lb
Remarks

L-3/T-1/ChE Date : 19/10/2019

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **ChE 303** (Mass Transfer I)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE** Questions

Assume reasonably if any additional data/information is required

1. (a) How can the direction of mass transfer be reversed in a gas/liquid system as it is in a complete gas plant? What controls whether a column is a stripper or an absorber? **(5+4)**

   (b) State all the assumptions required for the derivation of operating line for absorption. Justify the representation of absorption equilibrium data by Henry's law constant. **(4+5)**

   (c) We wish to design a stripping column to remove carbon dioxide from water. This is done by heating the water and passing it countercurrent to a nitrogen stream in a staged stripper. Operation is at 60°C and 1 atm. The water contains 9.2×10^{-6} mole fraction CO_2 and flows at 100,000 lb/hr. Nitrogen (N_2) enters the column as pure nitrogen and flows at 2500 ft^3/hr. **(17)**

   Nitrogen is at 1 atm and 60°C. We desire an outlet water concentration that is 2×10^{-7} mole fraction CO_2. Ignore nitrogen solubility in water and ignore the volatility of the water. The Henry's law constant at 60°C is 3410. Determine the number of stages needed using Kremser equation.

2. (a) In the production of sodium hydroxide by the lime soda process, a slurry of calcium carbonate particles in a dilute sodium hydroxide solution results. A five-stage counter current washing system is used. The underflow entrains approximately 3.75 kg liquid/kg dry calcium carbonate solids. The inlet water is pure water. If 10 kg wash water/kg dry calcium carbonate solids is used, predict the recovery of NaOH in the wash liquor. **(17)**

   (b) Explain properly how leaching differs from washing. Justify adequately the use of effective equilibrium constant for leaching. **(6+6)**

   (c) State only whether the following processes are washing or leaching: **(6)**

   (i) Recovering oil from soybeans (Washing/leaching)

   (ii) Recovery sugar from sugar cane (Washing/leaching)

   (iii) Isolating salt from wet sand obtained through mining from the ocean (Washing/leaching)

   (iv) Obtaining pharmaceutical products from plant roots. (Washing/leaching)

3. (a) Assume that you are extracting acetic acid from water with isopropylether in a countercurrent casecade Equilibrium data are given as right triangular diagram. The column has three equilibrium stages. The entering feed rate is 500 kg/h. The feed is 40 wt% acetic acid and 60 wt% water. The exiting extract stream has a flow rate of 1250 kg/h and is 20 wt% acetic acid. The entering extract stream (which is not pure isopropyl ether) contains no water. With the help of clear hand drawing and proper labeling, demonstrate the determination of- **(13)**

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(i) exit raffinate concentration

(ii) required entering extract stream concentration

(b) Write a short note on the methods of locating Δ, difference point for stage-by-stage calculation in triangular diagram. **(6)**

(c) A water solution containing 0.005 mole fraction benzoic acid is to be extracted using pure benzene as the solvent. If the feed rate is 100 moles/hr and the solvent rate is 10 moles/hr, find the number of equilibrium stages required to reduce the water concentration to 0.0001 mole fraction benzoic acid. Operation is isothermal at 6°C, where equilibrium data can be represented as **(16)**

Mole fraction of benzoic acid in water = 0.0446 × (mole fraction of benzoic acid in benzene).

4. (a) Select and justify appropriate type(s) of extractor when it is required to handle- **(4+4)**

   (i) liquids containing suspended solids

   (ii) Corrosive material

   (b) In the content of staged distillation column design- **(6)**

   (i) The basic design method for determining column diameter determines U_{flood}. Is this a vapor or a liquid velocity? How is the velocity of the other phase (liquid or vapor) included in the design procedure?

   (ii) State and explain the reason why the notched weirs have better turndown characteristics than straight weirs. **(5)**

   (iii) Intermediate feeds should not be introduced into a downcomer. Explain why not **(5)**

   (iv) Describe rank sieve, valve and bubble cap trays on the basis of efficiency and turndown. **(5)**

   (v) Several different column areas are used in column design. Define and contrast: net area, active area and hole area. **(6)**

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) Draw the schematic diagram of a flash distillation system. Label the diagram and describe the working principle. **(10)**

   (b) We are feeding 100 kmol/h of a 45 mole% propane and 55 mole% n-pentane feed to a flash distillation system. We measure the outlet vapor and liquid mole fractions leaving the flash drum, which is an equilibrium stage. It has been obtained that $y_{propane}$ is 0.8 and $x_{propane}$ is 0.2162. **(7+8=15)**

   Find: (i) L and V

   (ii) T_{drum} and P_{drum}

   where symbols have their usual meanings.

Contd P/3

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(c) A vertical flash drum is to flash a liquid feed of 1500 lbmol/h that is 40 mole% n-hexane and 60 mole% n-octane at 101.3 kPa (1 atm). We wish to produce a vapor that is 60 mole% n-hexane. Solution of the flash equations with equilibrium data gives x_H = 0.19, T_{drum} = 378K and V/F = 0.51. What size flash drum is required? Note that, symbols have their usual meanings. Consider, K_{drum} = 0.4433. **(10)**

6. (a) Distinguish between bubble regime and froth regime. Also write about the difficulties in distillation. **(4+3=7)**

   (b) Write the overall external balance equations (mass balance, energy balance and equilibrium relations) for a binary distillation column with necessary diagram. From them, derive the equations to calculate the distillate and bottom product. **(6+2=8)**

   (c) A distillation column separating ethanol from water is shown in 'Figure for Q 6(c): **(20)** Pressure of the system is 1 kg/cm^2. Instead of having a reboiler, steam (pure water vapor) is injected directly into the bottom of the column to provide heat. The injected steam is a saturated vapor. The feed is 30 wt% ethanol and is at 20 °C. Feed flow pate is 100 kg/min. Reflux is a saturated liquid. We desire a distillate concentration of 60 wt% ethanol and a bottom product that is 5 wt% ethanol. The steam is input at 100 kg/min flow rate. What is the external reflux ratio L/D?

7. (a) What is Murphree vapor Efficiency, E_{MV}? Describe the Murphree Efficiency Model with a neat diagram and prove that E_{MV} can be greater than 1. **(4+6=10)**

   (b) We wish to do a simple batch distillation (1 equilibrium contact) of a mixture of acetone and ethanol. The feed charge to the still pot is 80 mole% acetone. The final concentration in the still pot will be 40 mole% acetone. The final amount of material in the still pot is 2 kmol. Vapore-liquid equilibrium (VLE) data re presented below. Find the feed amount F, the average mole fraction of the distillate and the kmoles of distillate collected. **(25)**

x_A	0.10	0.15	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
y_A	0.262	0.348	0.417	0.524	0.605	0.674	0.739	0.802	0.865	0.929

8. A distillation column with 2 feeds is separating ethanol (E) and water (w) at a pressure of 1 atm. The column has a total condenser with saturated liquid reflux and a partial reboiler. Feed 1 is a saturated liquid and is 42 mole% ethanol. Feed 2 flowrate is 100 kmol/h. Feed 2 is 18 mole% ethanol and is a two phase mixture that is 30% vapor. The external reflux ratio is L/D = 1/2 and the distillate flowrate is 80 kmol/h. We desire a distillate mole fraction of x_D = 0.66 mole fraction ethanol and a bottoms that is x_B = 0.04 mole fraction ethanol. You can assume that CMO is valid. **(5+5+10+15=35)**

   (a) Find the flowrates F_1 and B

   (b) Find the liquid and vapor flowrates in the middle section, L′ and V′.

   (c) Determine and plot the operating lines. Be neat.

   (d) Find both optimum feed locations (above partial reboiler) and the total number of equilibrium stages needed. Step off stages from the bottom up. Be neat.

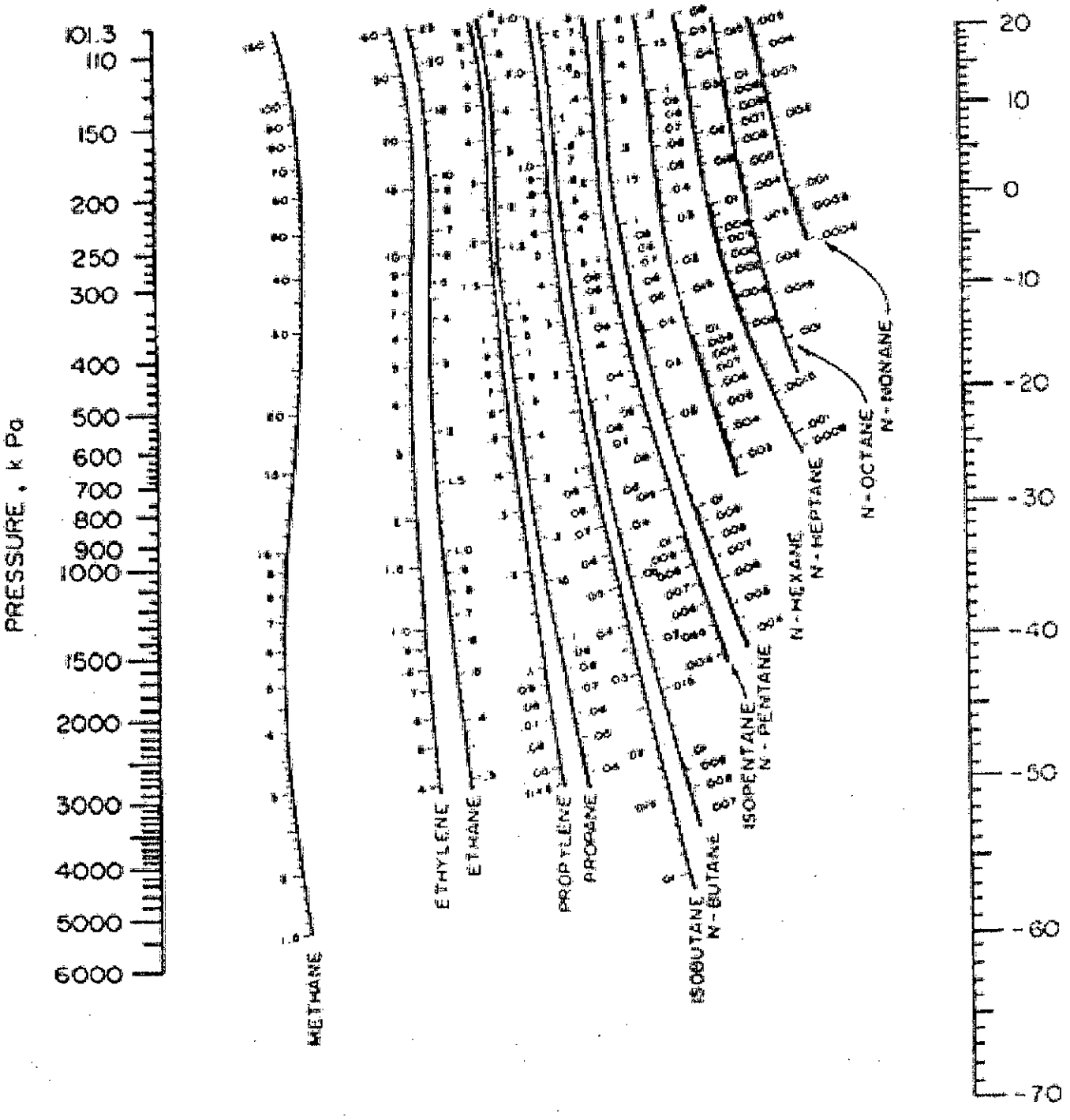

Figure for Q no. 5(b)

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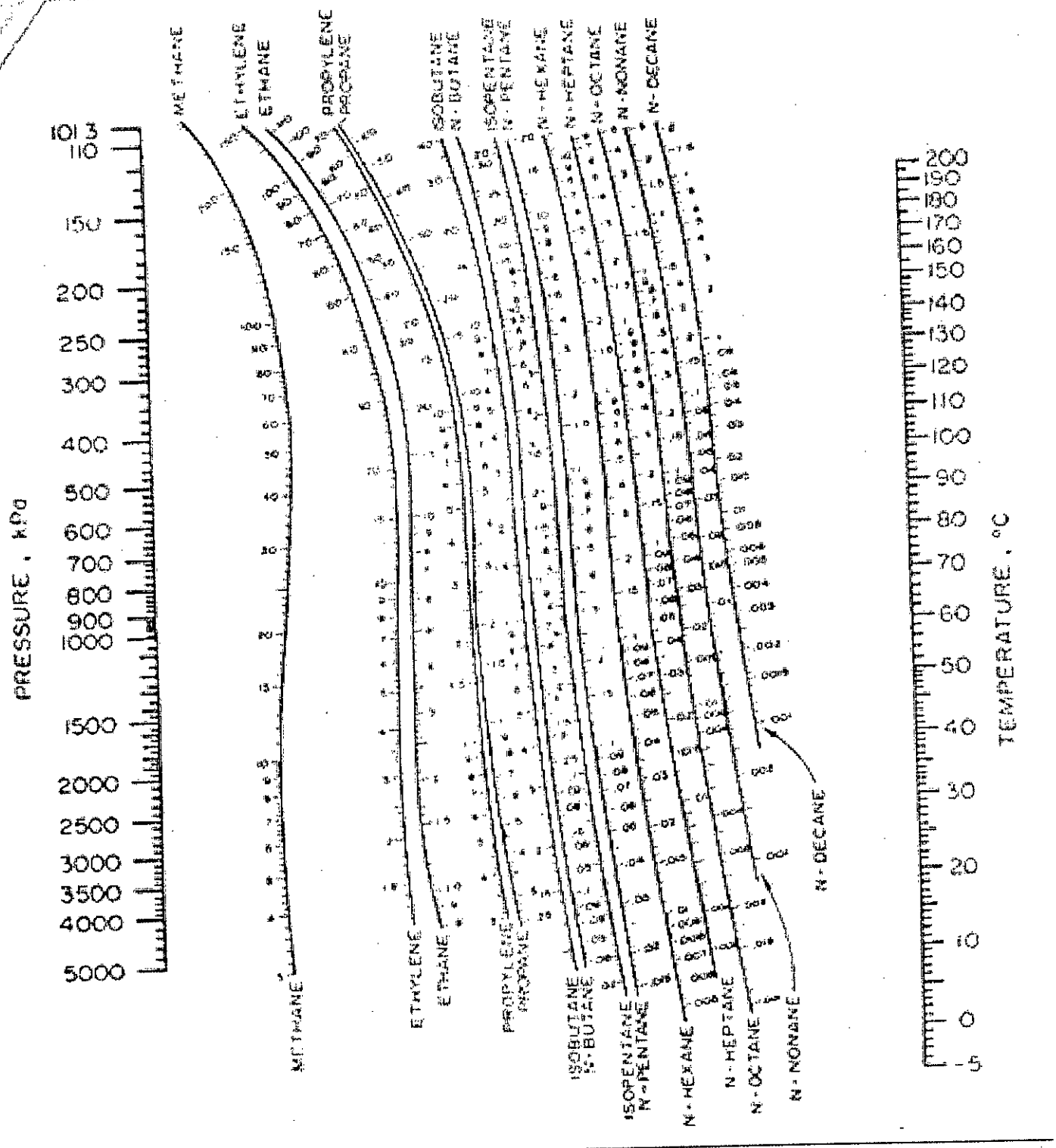

Figure for Q no. 5(b)

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Figure 2-4. Enthalpy-composition diagram for ethanol-water at a pressure of 1 kg/cm^2

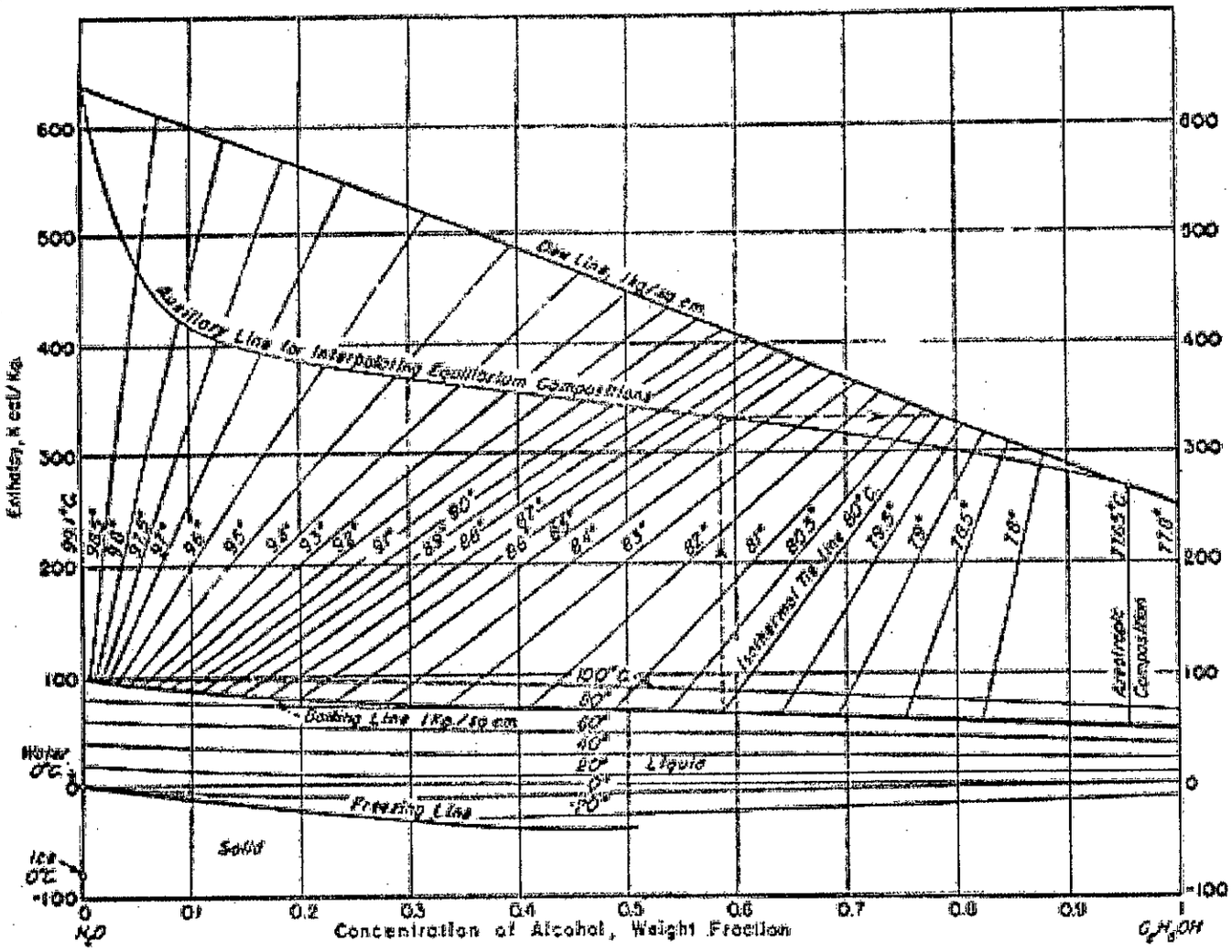

Figure for Q no. 6(c)

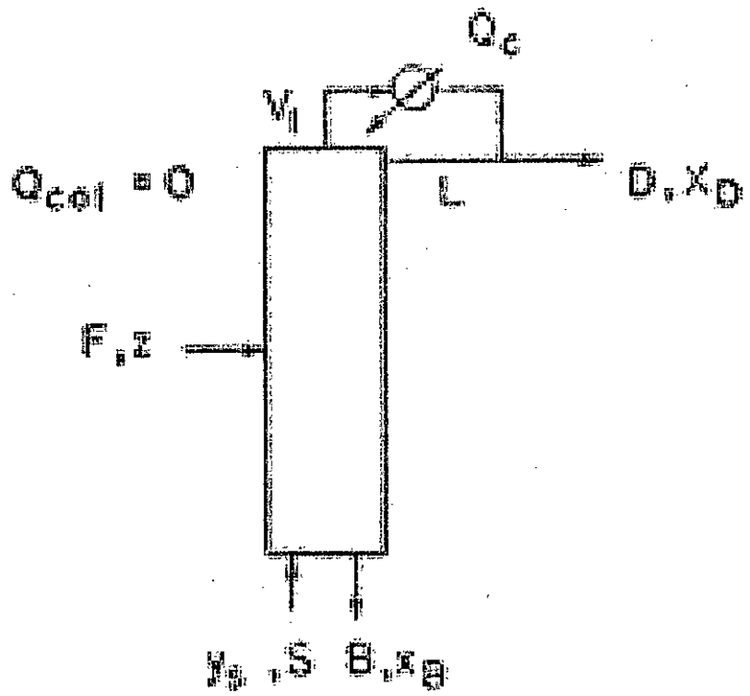

Figure for Q no. 6(c)

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Table 2-1. Vapor-liquid equilibrium data for ethanol and water at 1 atm y and x in mole fractions

x_{Etoh}	x_w	y_{etoh}	y_w	$T, °C$
0	1.0	0	1.0	100
0.019	0.981	0.170	0.830	95.5
0.0721	0.9279	0.3891	0.6109	89.0
0.0966	0.9034	0.4375	0.5625	86.7
0.1238	0.8762	0.4704	0.5296	85.3
0.1661	0.8339	0.5089	0.4911	84.1
0.2337	0.7663	0.5445	0.4555	82.7
0.2608	0.7392	0.5580	0.4420	82.3
0.3273	0.6727	0.5826	0.4174	81.5
0.3965	0.6035	0.6122	0.3878	80.7
0.5198	0.4802	0.6599	0.3401	79.7
0.5732	0.4268	0.6841	0.3159	79.3
0.6763	0.3237	0.7385	0.2615	78.74
0.7472	0.2528	0.7815	0.2185	78.41
0.8943	0.1057	0.8943	0.1057	78.15
1.00	0	1.00	0	78.30

R. H. Perry, C. H. Chilton, and S.O. Kirkpatrick (Eds.), *Chemical Engineers Handbook*, 4th ed., New York, McGraw-Hill, p. 13–5, 1963.

Table for Q no. 8

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **CHE 307** (Chemical Engineering Thermodynamics-II)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE.**

1. (a) Retrograde condensation is important in the operation of deep natural gas wells. True/False - Explain your answer. **(10)**

   (b) Carbonated water contains only CO_2 and H_2O. Determine the composition of the vapor and liquid phase in a sealed can of soda and the pressure exerted on the can at 20°C. Henry's constant for CO_2 at 20°C is about 1000 bar. The saturated vapor pressure of H_2O at 20°C is 0.0234 bar. **(15)**

   (c) For flash calculation, show that **(10)**

$$\sum \frac{z_i k_i}{1+\upsilon(k_i-1)}=1$$

   Symbols have their usual meanings.

2. (a) A liquid mixture of cyclohexane(1)/ phenol (2) for which $x_1 = 0.6$ is in equilibrium with its vapor at 144°C. Determine the equilibrium P and vapor composition y from the following information: **(20)**

   $\ln\gamma_1 = Ax_2^2 \qquad \ln\gamma_2 = Ax_1^2$

   At 144°C, $P_1^{sat} = 75$ *and* $P_2^{sat} = 32\,kPa$

   and $x_1^{az} = 0.30$ [form an azeotrope]

   (b) If $\overline{M}_i$ represents partial molal property of species i in solution, for binary mixture at constant temperature and pressure show that **(15)**

   $x_1 d\overline{M}_1 + x_2 d\overline{M}_2 = 0$

3. (a) How could you estimate fugacity co-efficient of species i in a binary mixture from Virial equation of state? **(15)**

   (b) The molar volume (cm^3/mol) of a binary liquid mixture at T and P is given by **(20)**

   $V = 120\,x_1 + 70\,x_2 + (15\,x_1 + 8\,x_2)\,x_1x_2$

   (i) Find the expressions for partial molar volume $\overline{V}_1$ and $\overline{V}_2$.

   (ii) Show that these expressions satisfy Gibbs/Duhem equation

   (iii) Plot molar volume and partial molar volume Vs composition and label the points of V_1, V_2, V_1^{∞} *and* V_2^{∞} with their values.

Contd 2

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4. (a) If excess Gibbs energy in a binary solution, G^E/x_1x_2RT is linear function of x_1, find the corresponding equation for $\ln\gamma_1$. **(15)**

(b) A single effect evaporator operating at atmospheric pressure concentrate 10% (wt) LiCl solution of 40%. The feed enters the evaporator at a rate 2 kg/s at 25°C. The normal boiling point of a 40% LiCl solution is about 132°C and its specific heat is estimated as 2.72 $kJkg^{-1}°C^{-1}$. What is the heat transfer rate in the evaporator? The enthalpy change per mole of water to produce 132°C superheated steam is 3636 kJ. **(20)**

SECTION – B

There are **FOUR** questions in this section. Question No. 5 is Compulsory and contains 45 marks. Answer any **Two** questions from the rest of the **Three** Questions.

5. Answer any nine (9) of the ten (10) questions below. Justify your answer with **adequate reasoning.** Answering without any reasoning will bear zero marks. **(9×5 = 45)**

(i) In vapor compression refrigeration cycle, the temperature of condenser is higher than the evaporator. It is the same coolant which evaporates at a lower temperature and condenses at a higher temperature in the evaporator and condenser respectively. This is achieved by using a compressor. In case of absorption refrigeration, there is no compressor, therefore, the pressure difference is maintained by -

a) An external heat-source ad vacuum pump.
b) A compressor
c) A pump
d) A throttle valve

(ii) If the total stoichiometric number $\nu=\sum\nu_i$ is positive, and increase in P at constant temperature (according to $\prod_i(y_i)^{\nu_i}=\left(\frac{p}{p_o}\right)^{-\nu}K$, symbols have their usual meanings)

a) will cause a shift of the reaction to the right
b) will cause a shift of the reaction to the left
c) will not affect the equilibrium at all
d) will cause an unpredictable effect

(iii) Using cascade refrigeration loop, higher cooling efficiency can be achieved. In this case, we need to connect them in a way that one loops evaporator becomes condenser for the other. What is the most critical factor to choose multiple-stage refrigeration over single stage -

a) Limits of temperature difference
b) Limits on operating pressures
c) Limits on the condenser
d) Limits on the evaporator

Contd 3

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Contd..... Q. No. 5

(iv) Linde process is a limiting case of Claude process. True/False (Justify)

(v) Phase stability criteria are applicable to both equilibrium and non-equilibrium states. True/False (Justify).

(vi) If heat is transferred from a low temperature level to a higher one, this requires _____ according to the second law. Fill in the gap and justify.

(vii) If $CaCO_3$ breaks down in a reaction: $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$. How many degrees of freedom available for this case?

a) 0 b) 1 c) 2 d) 3

(viii) In solid/vapor equilibrium, there would be a binary vapor phase containing species 1 and species 2. Among these two -

a) species 1 is insoluble in the solid

b) species 2 is insoluble in the solid

c) both of them are insoluble in the solid

d) both of them are soluble in the solid

(ix) Poynting factor becomes important when -

a) The pressure is low for solid/vapor equilibrium

b) The pressure is high for solid/vapor equilibrium

c) The solid solubility is high for solid/vapor equilibrium

d) The vapor phase enters in the critical state for solid/vapor equilibrium

(x) Among the following representations of the same stability criterion, which one is the most useful and why? (superscript t means total while rest of the symbols have their usual meanings)

a) $(dU^t)_{St,Vt} \leq 0$

b) $(dS^t)_{Ut,Vt} \geq 0$

c) $(dG^t)_{T,P} \leq 0$

d) None of the above

6. (a) What is the effect of temperature on the equilibrium constant? Explain in brief. **(5)**

(b) Derive the equation for liquid phase reactions for ideal solution $\left(\prod_i (x_i)^{\upsilon_i} = K\right)$

State all the necessary assumptions during the derivation. **(10)**

(c) The equilibrium compositions at 1000 K and 1 bar of a gas-phase system containing the species CH_4, H_2O, CO, CO_2 and H_2 are to be determined. In the initial unreacted state, there are 2 mol CH_4 ad 3 mol of H_2O present. Value of **(10)**

G_f^o *at* 1000 K are :

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Contd..... Q. No. 6(c)

$\Delta G^0_{fCH_4} = 19.72\,kJ/mol$ $\Delta G^o_{fH_2O} = -192.42\,kJ/mol$

$\Delta G^o_{fCO} = -200.24\,kJ/mol$ $\Delta G^o_{fCO_2} = -395.79\,kJ/mol$

From the system of equations for this system. You do not need to solve the equations, (necessary equation: $\Delta G^o_{f_i} + RT\ln\left(\frac{y_i\phi_i P}{p^o}\right) + \sum_k \lambda_k a_{ik} = 0$; symbols have their usual meanings)

(d) What are the advantages or disadvantages of determining equilibrium composition for reactions using Gibb's free energy minimization against equilibrium constant based calculation? **(5)**

7. (a) Derive the three conditions of stability for a system of binary liquid mixture in equilibrium with vapor phase. If the pressure is low enough for the system to consider as ideal gas, make necessary simplifications and show what happens if the mixture reaches azeotrope. **(15)**

(b) Interpret the figure below with respect to the stability criteria for binary mixture of liquids (not in equilibrium) **(5)**

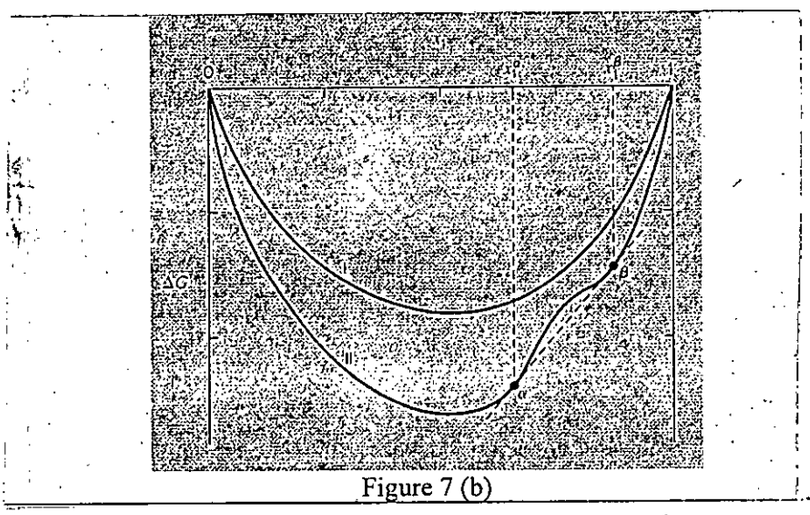

Figure 7 (b)

(c) The general equation of Solid/Vapor eq. is: $y_1 = \frac{P_1^{sat}}{P}\frac{\phi_1}{\phi}\exp\left(\frac{V_1^s(P - P_1^{sat})}{RT}\right)$. **(6+4=10)**

Simplify the equation for high pressure applications and interpret the figure below (no numerical calculation is necessary).

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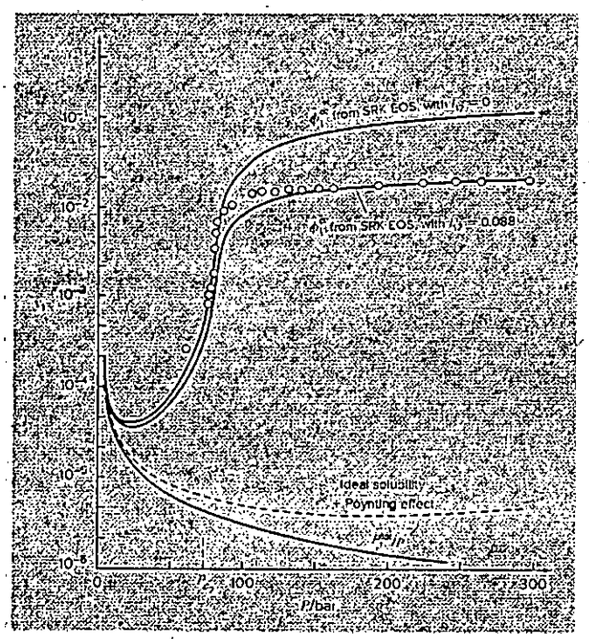

Figure 7(c)

8. (a) A house has a winter heating requirement of 29 kJ/s and a summer cooling requirement of 55 kJ/s. Consider a heat-pump installation to maintain the house temperature at 20°C in winter and 25°C in summer. This requires circulation of the refrigerant through interior exchanger coils at 30°C in winter and 5°C in summer. Underground coils provide the heat source in winter and the heat sink in summer. For a year-round ground temperature of 15°C, the heat-transfer characteristics of the coils necessitate refrigerant temperatures of 10°C in winter and 25°C in summer. What are the minimum power requirements for winter heating and summer cooling? **(8)**

(b) A refrigerated space is maintained at -20°C, and cooling water is available at 21°C. Refrigeration capacity is 120,000 kJ/h. The evaporator and condenser are of sufficient size that a 5°C minimum-temperature difference for heat transfer can be realized in each. The refrigerant is 1,1,1,2 - tetrafluoroethane (HFC-134a), (a) What is the value of ω for a Carnot refrigerator? (b) Calculate the circulation rate and ω for a vapor-compression cycle in Figure 8(b1) if the compressor efficiency is 0.80, (See Table 9.1 and Figure 8(b2) for necessary data). **(4+9=13)**

(c) What is absorption refrigeration cycle? Draw a neat sketch of the absorption refrigeration process and explain its working principle. **(2+7=9)**

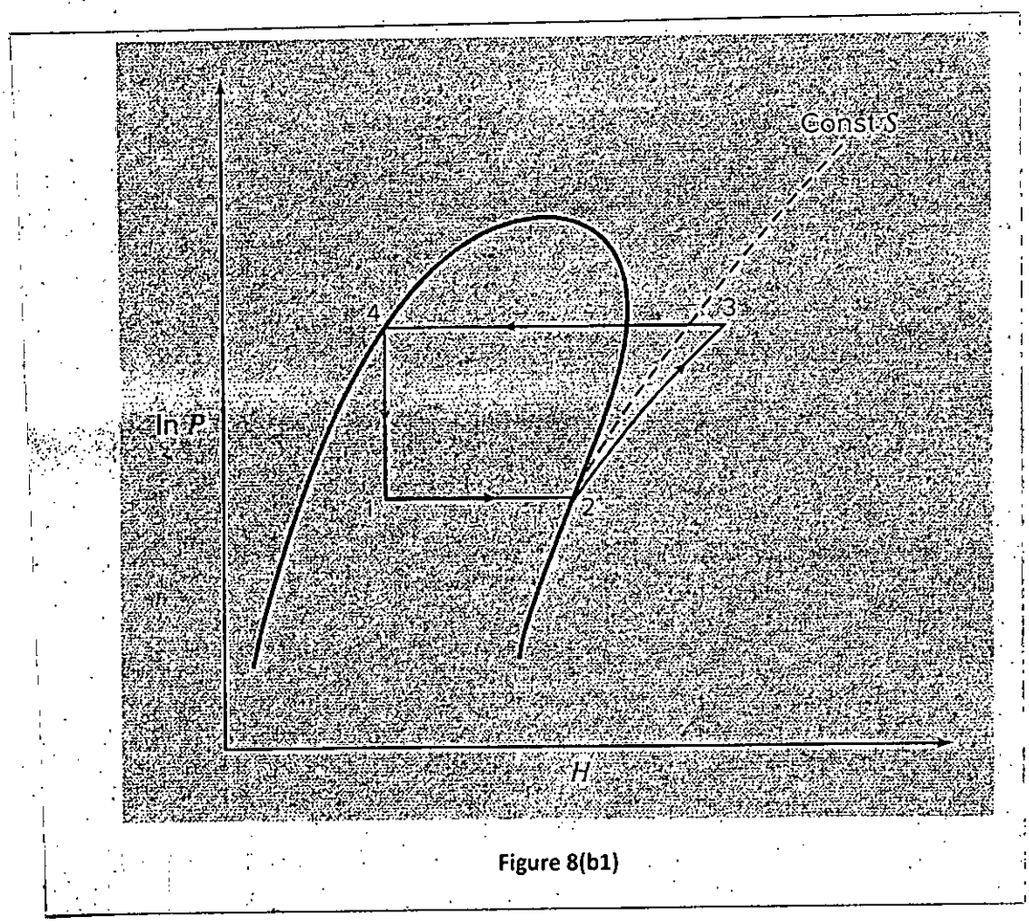

Figure 8(b1)

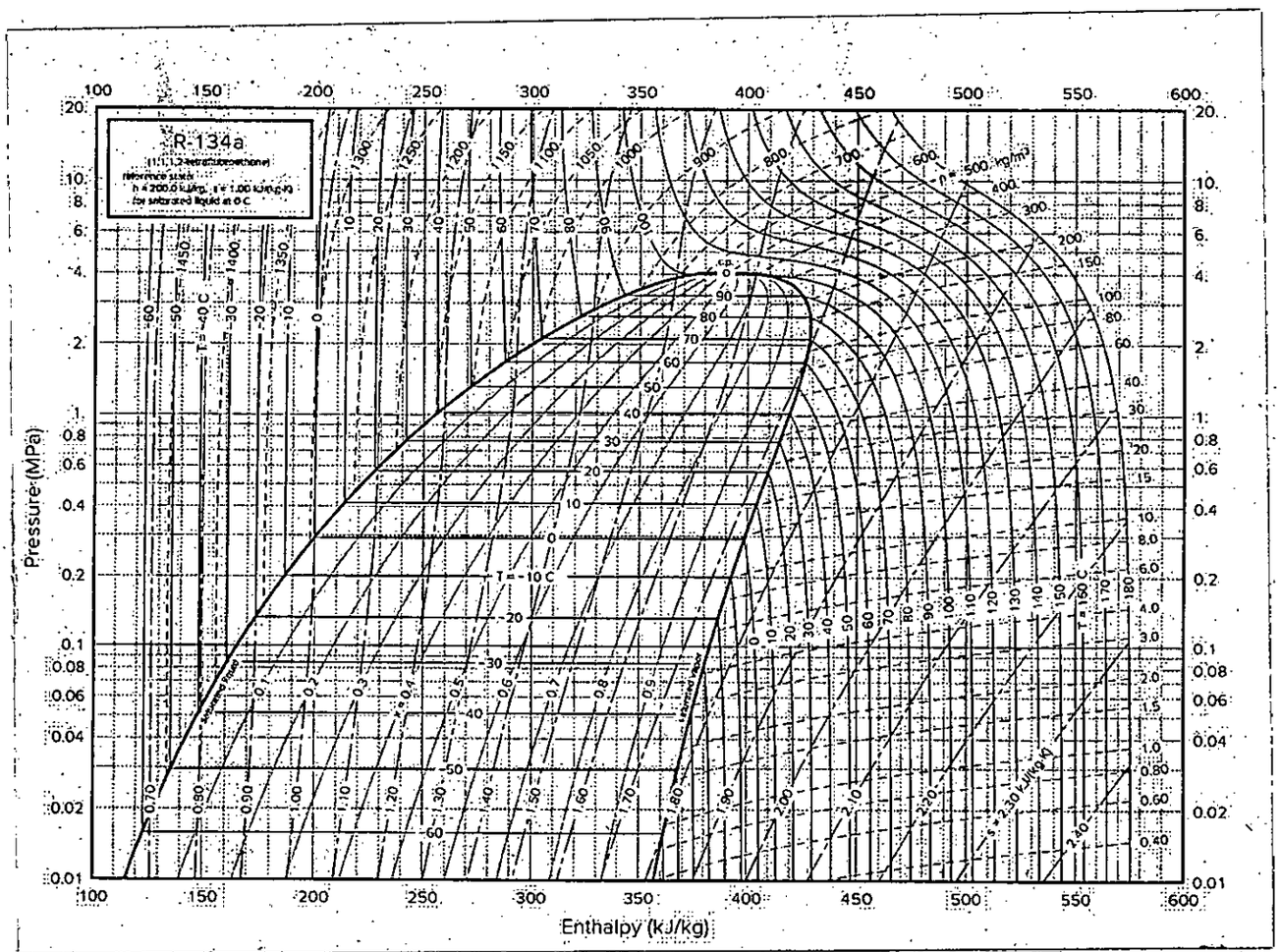

Figure 8(b2)

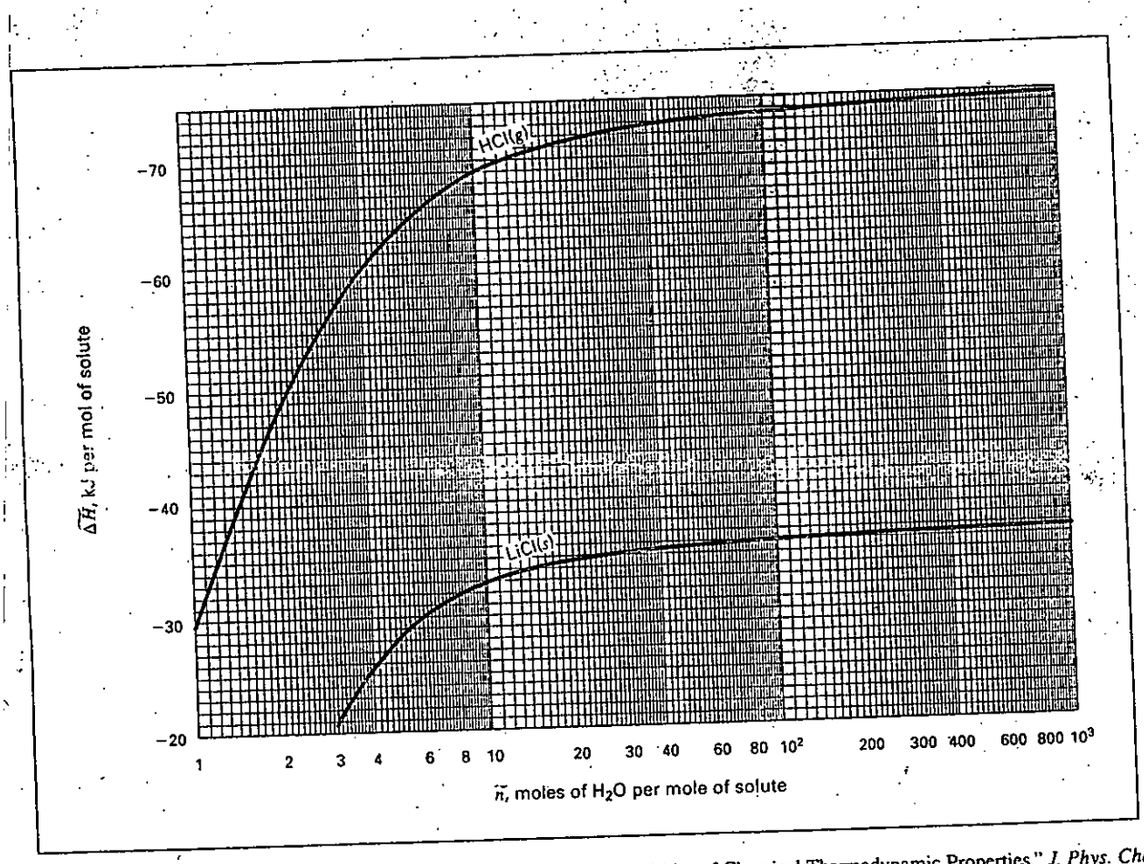

Figure 12.14: Heats of solution at 25°C. (Based on data from "The NBS Tables of Chemical Thermodynamic Properties," *J. Phys. Chem. Ref. Data*, vol. 11, suppl. 2, 1982.)

Table 9.1: Properties of Saturated 1,1,1,2-Tetrafluoroethane (R134A)†

		Volume $m^3 \cdot kg^{-1}$		Enthalpy $kJ \cdot kg^{-1}$		Entropy $kJ \cdot kg^{-1} \cdot K^{-1}$	
T(°C)	P (bar)	V^l	V^v	H^l	H^v	S^l	S^v
−40	0.512	0.000705	0.361080	148.14	374.00	0.796	1.764
−35	0.661	0.000713	0.284020	154.44	377.17	0.822	1.758
−30	0.844	0.000720	0.225940	160.79	380.32	0.849	1.752
−25	1.064	0.000728	0.181620	167.19	383.45	0.875	1.746
−20	1.327	0.000736	0.147390	173.64	386.55	0.900	1.741
−18	1.446	0.000740	0.135920	176.23	387.79	0.910	1.740
−16	1.573	0.000743	0.125510	178.83	389.02	0.921	1.738
−14	1.708	0.000746	0.116050	181.44	390.24	0.931	1.736
−12	1.852	0.000750	0.107440	184.07	391.46	0.941	1.735
−10	2.006	0.000754	0.099590	186.70	392.66	0.951	1.733
−8	2.169	0.000757	0.092422	189.34	393.87	0.961	1.732
−6	2.343	0.000761	0.085867	191.99	395.06	0.971	1.731
−4	2.527	0.000765	0.079866	194.65	396.25	0.980	1.729
−2	2.722	0.000768	0.074362	197.32	397.43	0.990	1.728
0	2.928	0.000772	0.069309	200.00	398.60	1.000	1.727
2	3.146	0.000776	0.064663	202.69	399.77	1.010	1.726
4	3.377	0.000780	0.060385	205.40	400.92	1.020	1.725
6	3.620	0.000785	0.056443	208.11	402.06	1.029	1.724
8	3.876	0.000789	0.052804	210.84	403.20	1.039	1.723
10	4.146	0.000793	0.049442	213.58	404.32	1.049	1.722
12	4.430	0.000797	0.046332	216.33	405.43	1.058	1.721
14	4.729	0.000802	0.043451	219.09	406.53	1.068	1.720
16	5.043	0.000807	0.040780	221.87	407.61	1.077	1.720
18	5.372	0.000811	0.038301	224.66	408.69	1.087	1.719
20	5.717	0.000816	0.035997	227.47	409.75	1.096	1.718
22	6.079	0.000821	0.033854	230.29	410.79	1.106	1.717
24	6.458	0.000826	0.031858	233.12	411.82	1.115	1.717
26	6.854	0.000831	0.029998	235.97	412.84	1.125	1.716
28	7.269	0.000837	0.028263	238.84	413.84	1.134	1.715
30	7.702	0.000842	0.026642	241.72	414.82	1.144	1.715
35	8.870	0.000857	0.023033	249.01	417.19	1.167	1.713
40	10.166	0.000872	0.019966	256.41	419.43	1.191	1.711
45	11.599	0.000889	0.017344	263.94	421.52	1.214	1.709
50	13.179	0.000907	0.015089	271.62	423.44	1.238	1.70
55	14.915	0.000927	0.013140	279.47	425.15	1.261	1.705
60	16.818	0.000950	0.011444	287.50	426.63	1.285	1.702
65	18.898	0.000975	0.009960	295.76	427.82	1.309	1.699
70	21.168	0.001004	0.008653	304.28	428.65	1.333	1.696
75	23.641	0.001037	0.007491	313.13	429.03	1.358	1.691
80	26.332	0.001077	0.006448	322.39	428.81	1.384	1.685

L-3/T-1/CHE Date : 02/11/2019

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **CHE 451** (Fuels and Combustion Science)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) With a neat sketch, describe the working principle of a thermogravimetric analyzer. What are the uses of this instrument for fuel analysis? **(6+4=10)**

   (b) Biomass is typically combusted at 550°C for fixed carbon determination while coal is combusted at 900°C. Why? **(6)**

   (c) Higher heating value of a fuel is 25 MJ/kg on as received basis. The moisture content is 10% (w/w) and ash content is 8% (w/w). Amount of water produced during combustion is 0.8 g/g of fuel. What is the lower heating value of the fuel on moisture and ash free basis? **(12)**

   (d) With a block diagram, show that the energy efficiency is increased in the case of a combined heat and power (CHP) plant. **(7)**

2. (a) What are the two types of kinetic models available for combustion (reaction) modeling? Write down the equation and explain their differences. **(4+4=8)**

   (b) Reaction rate constant (k) is dependent on both temperature and concentration of the reactant (gas). If the temperature is constant, k is only dependent on the changes in concentration. In that case, the equation can be expressed as: Reaction Rate, $\frac{dx}{dt}=k(Cco_2)f(x)$. Consider this reaction follows volumetric model for f(x). Using the values for CEC from Figure 2(b), determine the reaction order, n and reaction rate, R at conversion, x = 0.2. **(15)**

   (c) What are the differences of pyrolysis and devolatilization? Describe the main features of pyrolysis of a biomass particle. Do you think it is necessary to model pyrolysis with distributed activation energy model (refer to the formula sheet)? If so, why? **(4+4+4=12)**

3. (a) What are the benefits of performing thermodynamics equilibrium calculation over elementary calculation for combustion? Mention the factors that influence reaching equilibrium for combustion. **(6+4=10)**

   (b) During combusting a fuel, the following reactions take place- **(5)**

$$C(s) + CO_2 \leftrightarrow 2CO \quad (1)$$

$$CO_2 + H_2 \leftrightarrow CO + H_2O \quad (2)$$

$$H_2O \leftrightarrow H_2 + \frac{1}{2}O_2 \quad (3)$$

$$O_2 \leftrightarrow 2O \quad (4)$$

Contd P/2

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Contd..... Q. No. 3(b)

All these reactions are in equilibrium. Write down the equation for Kp for reaction (1) and (2) (see formula sheet for reference). If you make any assumption, clarify.

(c) The coal analysis for a power plant is as follows (w/w%): C: 63.4%, H: 3.9%, S: 0.8%, O: 9%, N: 1.6%, Ash 12.3%, Moisture: 9%. The higher heating value can be determined by using any of the formulas from the formula sheet attached. The air and coal enter the boiler at 25°C. For complete combustion of the fuel, 25% excess air is supplied. During the combustion process, 1.5% of the total fuel energy is lost to the surroundings. Also, the ash comes out of the furnace at 300°C incurring heat loss (heat capacity of ash is 0.9kJ/kg.K). The fuel gas from the process leaves the final heat exchanger at 130°C (heat capacity of the flue gas is 0.029 kJ/mol.K and consider the average molecular weight of flue gas is 30). Another loss occurs from heating the fuel itself to 800°C for combustion (heat capacity for coal is 1.2kJ/kg.K). Considering all the losses, calculate the amount of coal in ton to be supplied to the boiler to ensure a supply of 100 MW of useful heat to the power generation. **(20)**

4. (a) The first step of combustion and gasification is pyrolysis. During pyrolysis, heat transfer inside the fuel particle is a critical step. The following represents the heating and pyrolysis process of a fuel particle: **(8+12=20)**

$$\rho C_p \frac{\partial T_p}{\partial t} = \lambda \left[\frac{\partial^2 T_p}{\partial r^2} + \frac{b-1}{r} \frac{\partial T_p}{\partial r} \right] + q_{pyro} \left(-\frac{d\rho}{dt} \right)$$

If the fuel particle has a shape like a flat plate, simply the equation accordingly. Also the heat of reaction for pyrolysis can be considered as negligible with respect to the heat transferred for particle heating.

Based on the simplified equation, derive the equation for implicit (finite difference) method to solve the problem. (Hint: the final form of the equation is available in the formula sheet)

(b) Pyrolysis, gasification and combustion are overlapping phenomena. True/False. Explain. **(5)**

(c) What do you understand by multi-scale combustion modeling? Show the progressive nature of combustion modeling in different scales with a diagram. **(10)**

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SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) What are the boiler types based on their operating pressure? Give their operating pressures, fluid phase behavior and efficiency rating spread. **(3+6)**

(b) What type of boiler efficiency is performed for routine performance check?-Why? List the items one should require to measure the boiler efficiency for routine check. **(1+2+4)**

(c) The following information are given for an oil fired boiler:

Ultimate analyses of the fuel oil: C: 82%; H_2:14%; S: 3%; O_2: 1%

GCV of oil: 10,000 kcal/kg

Stack gas condition: O_2: 7%; CO_2: 11%; Flue gas temperature 250°C; Average specific heat capacity of flue gas: 0.25 kcal/kg°C.

Ambient air temperature : 30°C

Humidity of air : 0.018 kg/kg of dry air **(19)**

The latent heat of vaporization for water: 540 kcal/kg

Average specific heat capacity of water: 0.48 kcal/kg°C.

Find out the boiler efficiency. State all the assumptions clearly you require finding the efficiency.

6. (a) Show the progression of solid fuel conversion during gasification including temperature ranges and mechanisms. What do you know about water gas reactions,. Boudouard reaction and water gas shift reaction in gasification process? **(8+5)**

(b) Name a non-conventional gasifier and describe its working principle with schematic diagram. How does it differ from conventional gasifier? **(1+10+12)**

(c) Describe the MDEA technique for removing acid gases from IGCC process with diagram. **(9)**

7. (a) What does cogeneration mean? Show schematically a cogeneration system using closed cycle gas turbine. **(2+4)**

(b) Show the schematic of Rankine cycle with superheating and reheating provisions. Describe its working principle using T-S and T - $\Sigma \dot{Q}$ diagrams. **(4+4+4)**

(c) Summit group is going to establish a 250 MW national gas based combined cycle power plant at Meghnaghat. The CAPEX of such plant is 900 $/kW and the OPEX is 0.04 $/kWh. The plant useful life is considered as 5 years after which the market value of the plant is 22.5 million $. The company is expected to sell the electricity at a price of 0.094 $/kWh. Considering Income Tax Rate 35% and Interest Rate 15%, evaluate the economic feasibility of the plant using present worth method. **(17)**

Contd P/4

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8. (a) What is oxy-fuel combustion? -Show with diagram and briefly explain the process. Why is the size of oxy fired CFB boiler smaller than traditional CFB boiler? **(6+2)**

(b) Draw a typical CLC process diagram and briefly state its function. **(6)**

(c) Why do we use HTT process? What are the differences in operating variables of HTC and HTL? What are the optimal biomass processing conditions for fast Pyrolysis process? **(2+2+2)**

(d) What is GGE? Gasoline HHV is 42 MJ/kg and the density is 740 kg/m^3. The selling price of gasoline is 2.8 $/gallon. If a liquid fuel has a LHV of 18 MJ/kg and can be sold at 2 $/gallon (0.68 $/kg), what is the price of the fuel per GGE? **(2+6)**

(e) What are flame cone and flame front of a Bunsen flame? Explain the Damkohler analysis on flame speed. **(3+4)**

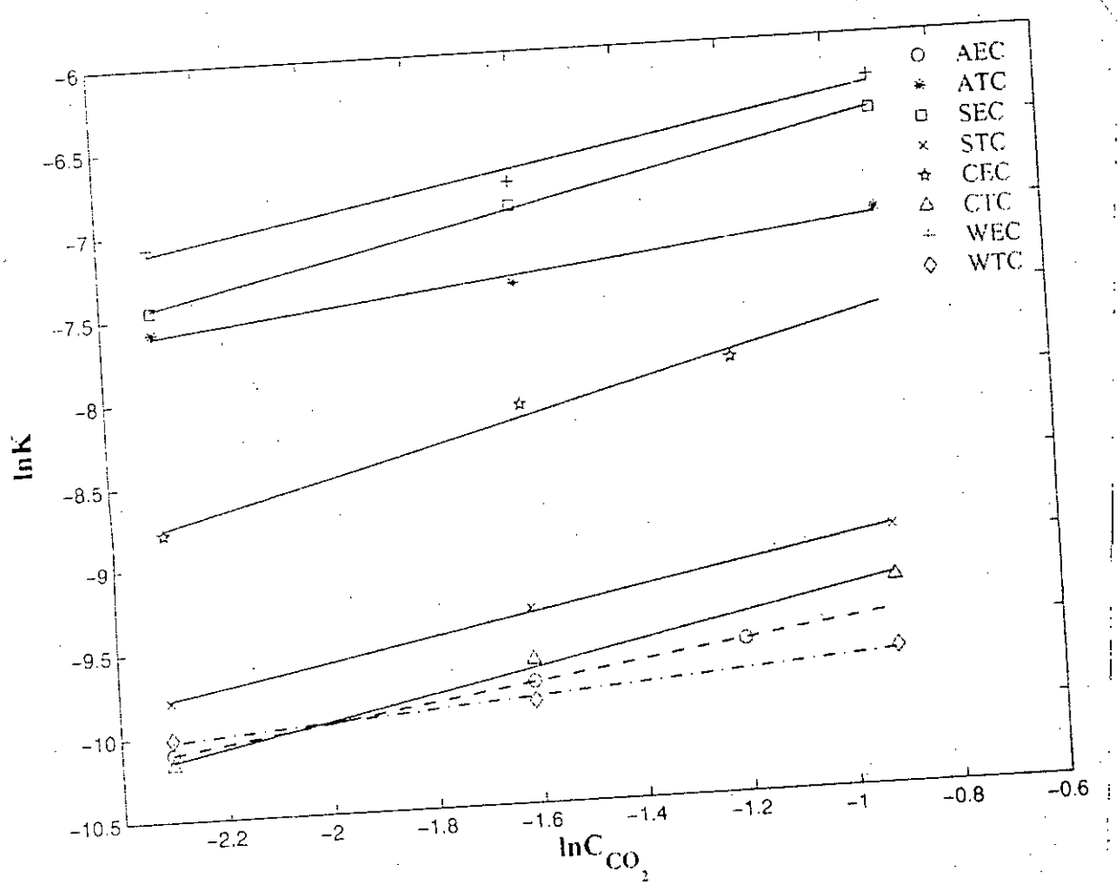

Figure 2b

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Formulae Sheet

$$k\frac{\partial^2 T}{\partial x^2} = \frac{\partial T}{\partial t}$$

$$\frac{\partial^2 T}{\partial x^2} \cong \frac{T_{i+1}^{l+1} - 2T_i^{l+1} + T_{i-1}^{l+1}}{(\Delta x)^2}$$

$$k\frac{T_{i+1}^{l+1} - 2T_i^{l+1} + T_{i-1}^{l+1}}{(\Delta x)^2} = \frac{T_i^{l+1} - T_i^l}{\Delta t}$$

$$-\lambda T_{i-1}^{l+1} + (1 + 2\lambda)T_i^{l+1} - \lambda T_{i+1}^{l+1} = T_i^l$$

Heat transfer

$$\rho C_p \frac{\partial T_p}{\partial t} = \lambda\left[\frac{\partial^2 T_p}{\partial r^2} + \frac{b-1}{r}\frac{\partial T_p}{\partial r}\right] + q_{pyro}\left(-\frac{d\rho}{dt}\right)$$

Reaction kinetics

Relate ρ to the mass loss due to combustion

$$-\frac{d\rho_b}{dt} = -k\rho_b$$

$$\frac{d\rho_c}{dt} = \upsilon_c k\rho_b$$

$$k = A\exp(-E/RT)$$

$$t_{conv} = \frac{\rho_p C_p d_p}{6h}$$

$$t_{rad} = \frac{\rho_p C_p d_p}{6\sigma\epsilon(T_g+T_p)(T_g^2+T_p^2)}$$

$$t_{cond} = \frac{\rho_p C_p d_p^2}{36\lambda}$$

$$t_{pyro} = \frac{1}{k_{pyro}}$$

HHV= -1.3675 + 0.3137C + 0.7009H + 0.0318O Or

HHV= 0.3491C + 1.1783H + 0.1005S – 0.1034O – 0.0151N – 0.0211A

$$g_i = g_i^{\ o} + RT.\ln(\frac{p_i}{p_o})$$

$$\frac{a\cdot g_A^0 + b\cdot g_B^0 - r\cdot g_R^0 - s\cdot g_S^0}{\bar{R}\cdot T} = \ln\left(\frac{p_R^r\cdot p_S^s}{p_A^a\cdot p_B^b}\cdot p_0^{(a+b-r-s)}\right)$$

$$\ln K_p = \frac{a\cdot g_A^0 + b\cdot g_B^0 - r\cdot g_R^0 - s\cdot g_S^0}{\bar{R}\cdot T}$$

$$\frac{N_R^r \cdot N_S^s}{N_A^a \cdot N_B^b} \cdot N_{tot}^{(a+b-r-s)} \cdot \left(\frac{p_{tot}}{p_0}\right)^{(r+s-a-b)} = K_p$$

Volumetric model:

$$\frac{dx}{dt} = k(1-x)$$

Shrinking core model:

$$\frac{dx}{dt} = k(1-x)^{\frac{2}{3}}$$

$$x = 1 - \int_0^\infty \exp\left(-\int_0^t k dt\right) f(E) dE$$

Standard deviation, $\sigma = \sqrt{\frac{1}{1-N}\sum_1^N (E - meanE)^2}$

Gaussian distribution, $f(E) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(E-meanE)^2}{2\sigma^2}}$

$$-\frac{\partial q}{\partial x} = \rho C \frac{\partial T}{\partial t}$$

$$k\frac{\partial^2 T}{\partial x^2} = \frac{\partial T}{\partial t}$$

$$\rho C_p \frac{\partial T_p}{\partial t} = \lambda_1 \left[\frac{\partial^2 T_p}{\partial r^2} + \frac{b-1}{r}\frac{\partial T_p}{\partial r}\right] + q_{pyro}\left(-\frac{d\rho}{dt}\right)$$

$$\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1}^{l} - 2T_i^{l} + T_{i-1}^{l}}{\Delta x^2}$$

$$\frac{\partial T}{\partial t} = \frac{T_i^{l+1} - T_i^{l}}{\Delta t}$$

$$\frac{\partial^2 T}{\partial x^2} = \frac{T_{i+1}^{l} - 2T_i^{l} + T_{i-1}^{l}}{\Delta x^2}$$

$$\frac{\partial T}{\partial t} = \frac{T_i^{l+1} - T_i^{l}}{\Delta t}$$

initial conditions ($0 \le r \le R$) are: $T_p = 300\ K$; $\rho_b = \rho_{b0}$; $\rho_c = 0$

At center, when $t \ge 0$

$$\lambda_1 \frac{\partial T_p}{\partial r} = 0$$

At surface, when $t \ge 0$

$$\lambda_1 \frac{\partial T_s}{\partial r} = h\left(T_g - T_s\right) + \sigma\varepsilon\left(T_g^4 - T_s^4\right)$$

$$\rho = \rho_b + \rho_c$$

$$C_p = \left(\rho_b C_{p.b} + \rho_c C_{p.c}\right)/\rho$$

$$\lambda_1 = (\rho_b \lambda_b + \rho_c \lambda_c)/\rho$$

$$\mathrm{Nu} = 2 + 0.6\mathrm{Re}_D^{0.5}\,\mathrm{Pr}_D^{1/3}$$

L-3/T-1/CHE Date : 06/11/2019

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **HUM 201** (Sociology)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) How do you define natural environment and man-made environment? **(10)**

   (b) Define global warming. Briefly explain the potential consequences of global warming. **(15)**

   (c) What are the impacts of human activities on the environment? **(10)**

2. (a) Discuss H. M. Jonson's explanation of conditions for successful learning. **(10)**

   (b) What is socialization? Explain primary socialization and anticipatory socialization with examples. **(10)**

   (c) Evaluate the roles of family, peers and educational institutions as important agents of socialization. **(15)**

3. (a) What do you know about capitalism? Briefly discuss the positive and negative consequences of capitalism. **(15)**

   (b) Write down the different evolutionary stages of city on the basis of Mumford's theory. **(10)**

   (c) Identify the major pollution issues in Dhaka City. **(10)**

4. Write short notes on any THREE of the following: **(35)**

   (a) The growth of cities

   (b) Mathusian population theory

   (c) Sources of social change

   (d) Causes of juvenile delinquency

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) Explain the underlying factors for developing sociology as an independent discipline. **(10)**

   (b) Write the differences between 'formalistic school' and 'synthetic school' of sociology. **(10)**

   (c) Discuss the functionalist theoretical perspective of sociology. **(15)**

6. (a) Define culture. Explain the role of culture as a normative system of a society. **(17)**

Contd P/2

HUM 201

Contd..... Q. No. 6

(b) 'Social structure of a group determines its culture'- Explain this statement with suitable with suitable examples. **(18)**

7. (a) Suppose you are a researcher, would like to research on the social impact of a fertilizer factory. How would you design your research work? **(20)**

   (b) Write the advantages and disadvantage of participant observation method. **(15)**

8. Write short notes on any three of the following: **(35)**

   (a) Functions of family.

   (b) Types of social mobility.

   (c) Recent trends of nuclear family.

   (d) Types of social stratification.

L-3/T-1/CHE Date : 06/11/2019

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **HUM 203** (Government)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) Write is nationalism? Discuss the merits of nationalism. **(15)**

   (b) Define constitution. Discuss various types of constitution with examples. **(20)**

2. (a) Discuss the importance of opposition party in parliamentary government. **(15)**

   (b) Explain the political rights and duties of a citizen in a state. **(20)**

3. (a) Discuss the causes of military intervention in politics in developing countries. **(15)**

   (b) Make a comparative discussion between unitary and federal forms of government. **(20)**

4. Write short notes on any three (3) of the following: **(35)**

   (a) Internationalism

   (b) Nature of dictatorship

   (c) Good Governance

   (d) Despotic government

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) Define state. Discuss the differences between society and state. **(15)**

   (b) What is bureaucracy? Discuss the principles of bureaucracy as proposed by Max Weber. **(20)**

6. (a) Discuss the significance of the language movement of 1952 with respect to the independence of Bangladesh. **(15)**

   (b) Define political party. Distinguish between political party and pressure group. **(20)**

7. (a) Discuss the main features of the political systems of United Kingdom (UK). **(15)**

   (b) What is UNO? Discuss of the major functions of UNO in times of globalization. **(20)**

8. Write Short note on any three of the following: **(35)**

   (a) Government

   (b) Socialism

   (c) Unwritten constitution

   (d) International mother language day

L-3/T-1/CHE Date : 06/11/2019

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **HUM 303** (Principles of Accounting)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) What are the different types of financial statements that usually published in the annual report? **(10)**

(b) Mr. "L" has the following transaction during his first month of operation in April, 2019.

April-1 : Stared his firm investing Tk. 350,000 cash.

April-3 : Paid repair expense for the month of April Tk. 4,000 in cash.

April-5 : Purchased machinery for office Tk. 60,000. Paid cash Tk. 50,000 and remaining amount will be paid later.

April-3 : Received Tk. 40,000 in cash by providing services.

April-10 : Paid Tk. 6,000 for telephone bill in cash for the month of April.

April-12 : Withdrew Tk. 8,000 for personal use by owner.

April-15 : Provided services to the customers but amount is not collected in cash amount Tk. 25,000.

April-22 : Paid Tk. 10,000 in cash related to date 5.

April-26 : Cash received from customers Tk. 10,000 related to date 15.

April-30 : Purchased a delivery van for office on credit Tk. 10,000.

Required: **(25)**

(i) Show the effects of above stated transaction on the accounting equation.

(ii) Also prepare an owners' equity statement for the month of April.

2. (a) Mr. D started his business on May 1, 2019. The following transactions took place during that month-

May 1: Invested Tk. 150,000 cash in the business.

May 5: Paid utility bill in cash Tk. 12,000.

May 12: Purchased office furniture on account Tk. 50,000.

May 27: Paid Tk. 30,000 in cash resulting from the transaction May 12.

May 28: Provide services to the clients in cash Tk.25,000.

Required: **(23)**

(i) Give journal entries for the month of May, 2019.

(ii) Prepare necessary ledger accounts.

(iii) Prepare a trial balance.

Contd P/2

HUM 303

(b) Following information is available for "Seashell Company".

Seashell Company
Income Statement
For the year ended December 31,2016

	Amount(Tk.)
Sales	**900,000**
Less: Sales returns and allowances	80,000
Net sales	**820,000**
Less: Cost of goods sold	300,000
Gross profit	**520,000**
Less: Operating expenses	100,000
Net income	**420,000**

Seashell Company
Balance Sheet
December 31,2016

Asset	Amount(Tk.)	Liabilities and Equity	Amount(Tk.)
Cash	35,000	Accounts payable	60,000
Accounts receivable	50,000	Other current liability	25,000
Inventory	90,000	Long term debt	80,000
Investments	75,000	Common stock (Tk. 10 par)	340,000
Plant asset (net)	400,000	Retained earnings	145,000
Total asset	**650,000**	**Total Liabilities and Equity**	**650,000**

Required: **(12)**

(i) Profit margin.

(ii) Asset turnover or Return on asset.

(iii) Return on equity (ROE).

(iv) Quick or acid test ratio.

(v) Earnings per share (EPS).

(vi) Inventory turnover.

3. (a) Write down the types of prepayments under adjusting entries and identify the types o adjustments applicable to each category. **(5)**

(b) The trial balance of "Popular Company" on May 31,2018 is given below-

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Contd….. Q. No. 3(b)

"Popular Company"
Trial Balance
May 31, 2018

Accounts Title	Debit (TK.)	Credit(Tk.)
Cash	30,000	
Accounts receivable	5,000	
Prepaid insurance	2,400	
Supplies	1,500	
Office furniture	15,000	
Accounts payable		9,500
Unearned service revenue		6,000
Capital		42,500
Service revenue		5,900
Salary expense	2,000	
Rent expense	1,000	
Maintenance expense	2,000	
Interest expense	4,000	
Drawings	1,000	
Total	63,900	63,900

Other Information:

Accrued rent is Tk. 600.

Maintenance expense incurred but not paid on May 31, Tk. 8,000.

Tk. 3,000 of service performed during the month but has not been recorded as of May 31.

Unearned service revenue of Tk. 1,500 has been earned.

Tk. 1000 of supplies has been used during the period.

Office equipment is being depreciated at Tk. 250 per month.

Accrued interest is Tk. 1500.

Required:

(i) Prepare necessary adjusting entries. **(30)**

(ii) Prepare an adjusted trial balance as at May 31, 2018.

4. (a) What is the classification of liability item under a classified balance sheet? **(5)**

(b) The following accounts are taken from the ledger balance of "G" company Ltd. on 31st December, 2018.

Contd P/4

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" G" Company Ltd
Trial Balance
31st December, 2018

Accounts Title	Debit (Tk.)	Credit (Tk.)
Cash	50,000	
Patent	10,000	
Utility payable		10,000
Accounts receivable	40,500	
Accounts payable		21,000
Capital		60,000
Sales revenue		185,200
Salary expense	12,000	
Prepaid rent	4,000	
Utility expense	1,000	
Rent expense	3,000	
Supplies	1,000	
Notes payable		7,300
Drawings	2,000	
Land	50,000	
Machinery	100,000	
Long term investment	50,000	
Unearned revenue		25,000
Wage payable		15,000
Total	**323,500**	**323,500**

Adjustments data:

(i) Tk. 5,000 of notes payable will be paid in 2019.

(ii) Amount of accrued rent Tk. 1,000.

Required: **(30)**

(i) Prepare an income statement.

(ii)Prepare at owners' equity statement and a classified balance sheet on 31st December, 2018.

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) What is meant by contribution margin ratio? How is this ratio useful in planning business operation? **(5)**

(b) Volter Company manufactures and sells a specialized cordless telephone for high electromagnetic radiation environment. The company's contribution margin income statement for the most recent year is given below: **(30)**

Sales (20,000 Units @ Tk. 60)	Tk. 1200,000
Less: Variable cost of Sales	900,000
Contribution margin	300,000
Less: Fixed cost for the period	240,000
Net Income	60,000

Contd P/5

HUM 303

Contd..... Q. No. 5(b)

Requirements:

(i) Compute the Company's CM ratio.

(ii) Compute the Company's break-even point in Units and in amounts.

(iii) Assume that sales increase by Tk. 400,000 next year. If cost behavior patterns remain unchanged, by how much will the company's net income increase?

(iv) Refer to the original data. Assume that next year management wants to earn a profit of Tk. 90,000. How many Units will have to be sold to earn this target profit?

(v) Refer to the original data, compute the company's margin of safety in Tk. and in percentage form.

(vi) Compute the degree of operating leverage at the present level of sales.

Assume that Company's sales increases by 8% next year. By what percentage would you expect net income to increase? Use degree of operating leverage to obtain your answer.

Verify your answer as calculate above by preparing a new contribution margin format income statement showing an 8% increase in sales.

6. (a) What is the basic difference between absorption costing and variable costing method. **(5)**

(b) Denton Company produces and sells a single product, cost data for the product are given below: **(30)**

Variable cost per unit	
Direct materials	Tk. 7
Direct Labour	10
Variable manufacturing overhead	5
Variable selling and administrative overhead	3
Fixed cost for the period	
Fixed manufacturing overhead	Tk. 315,000
Fixed selling and administrative overhead	245,000
Other information:	
Units produced	17,500
Units sold	15,000
Selling price per unit	Tk. 60

Requirement:

(i) Determine Unit Product cost under absorption costing and variable costing method.

(ii) Prepare income statements under the both methods.

7. (a) Classify costs according to cost behavior with examples. **(5)**

(b) The data below have been taken from the cost records of Beverly Hospital. A careful study by the company's cost analyst has determined that if the number of X-rays taken is 7000 the average cost is Tk. 4.14 per x-ray. If the number of x-rays taken is 3000, the average operating cost is Tk. 5.65 per x-ray. **(14)**

Contd P/6

HUM 303

Contd..... Q. No. 7(b)

Requirements:

(i) Using the high & low point method, determine the variable cost per x-ray and the fixed cost in total.

(ii) Express the variable cost and fixed cost in the form of $y = mx + c$

(iii) If the number of x-rays taken 4600, what total operating x-rays costs would you expect?

(c) The following costs and inventory data are taken from the accounting records of Meriwell Company for the year ended on December 31, 2018. **(16)**

Direct Labour cost	Tk. 70,000
Purchase of raw materials	118,500
Indirect Labour	30,000
Maintenance, Factory equipment	6,000
Advertising cost	90,000
Insurance, Factory	800
Sales commission	35,000
Administrative manager's Salary	55,000
Supervisor's Salary	12,000
Rent, Factory	30.000
Rent Office	25,000
Rent Showroom	13,000
Utilities factory	15,000
Supplies, office	3,000
Power and electricity	2500
Depreciation, factory equipment	30,000

Inventories	January 1	December 31
Raw materials	Tk. 7000	Tk. 15,000
Work-in-process	10,000	5,000
Finished goods	20,000	35,000

Requirements:

(i) Prepare a statement of cost of goods sold

(ii) Prepare an income statement if sales amount is Tk. 700,000.

8. (a) What are the purposes of cost allocation? **(5)**

(b) Phonex consulting provided outsourcing services and advice to both government and corporate clients. For costing purposes, phonex classifies its departments into two service departments (Human Resource and Information system) and two producing departments (Government consulting and corporate consulting). Overhead costs across the first quarter of 2018 are given below: **(18)**

Contd P/7

HUM 303

Contd..... Q. No. 8(b)

	Production Departments		Service Departments	
Overhead costs	Government Consulting	Corporate Consulting	Human resource	Information System
before allocation (Tk.)	87,56,000	124,52,000	600,000	240,000
Cost allocated by:				
Human resource	40%	35%	-	25%
Information System	30%	60%	10%	-

Requirements:

You are asked to allocate the service departments cost to the production departments using the following methods:

(i) Direct Method

(ii) Reciprocal service Method.

(c) Foley Company uses job-order costing system. The following data relate to the month of October, 2018: **(12)**

(i) Raw materials purchased on account Tk. 210,000

(ii) Raw materials issued to production Tk. 190,000 (80% direct and 20% indirect).

(iii) Direct labour cost incurred Tk. 49,000 and indirect labour cost incurred Tk. 21,000.

(iv) The company applies manufacturing overhead cost to production on the basis of Tk. 4. per machine hour. There were 75,000 machine hours recorded for October.

(v) Production orders costing Tk. 500,000 according to their job cost sheet were completed during October and transferred to finished goods.

(iv) Production orders that had cost Tk. 450,000 to complete according to their job cost sheet were shipped to customer during the month. These goods were sold at 50% above cost. The goods were sold on account.

Requirements:

Prepare Journal entries to record the above information.

L-3/T-1/CHE **Date : 02/11/2019**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **MATH 323** (Fourier, Integral, Harmonic Functions and Partial Differential Equations)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) Find the Fourier series for **(20)**

$$f(x)=\begin{cases} x+\dfrac{\pi}{2}, & -\pi<x<0 \\ \dfrac{\pi}{2}-x, & 0\le x<\pi \end{cases}$$

(b) Expand $f(x) = 2x$, $0 < x < 2$, in a half range sine series and cosine series. **(15)**

2. (a) Find the Fourier series for **(20)**

$$f(x)=\begin{cases} 1-x^2, & |x|<1 \\ 0, & |x|\ge 1 \end{cases}$$

and use Parseval's Identity to evaluate $\int_0^\infty \dfrac{(x\cos x-\sin x)^2}{x^6}dx.$

(b) Solve the integral equation $\int_0^\infty f(t)\cos(ut)dt=\begin{cases} 1-u, & 0\le u<1 \\ 0, & u\ge 1 \end{cases}$. **(15)**

Hence show that $\int_0^\infty \dfrac{\sin^2 u}{u^2}du=\dfrac{\pi}{2}$.

3. (a) Use Fourier cosine integral formula to show that **(18)**

$$e^{-x}\cos x=\frac{2}{\pi}\int_0^\infty \frac{u^2+2}{u^4+4}\cos(ux)du; \qquad x>0.$$

(b) Find the Fourier transform of $f(x)=\begin{cases} 1, & |x|\le\pi \\ 0, & |x|>\pi \end{cases}$ and deduce the value of $\int_0^\infty \dfrac{\sin u}{u}du.$ **(17)**

4. (a) Prove that $\int_0^\infty \dfrac{u\sin(mu)}{u^2+1}du=\dfrac{\pi}{2}e^{-m}$; $m>0$. **(10)**

(b) Find the solution of the boundary value problem

$\dfrac{\partial u}{\partial t}=\dfrac{\partial^2 u}{\partial x^2}$ where $0 < x < \pi$, $t > 0$, **(25)**

$u(0,t) = 1$, $u(\pi, t) = 3$, and $u(x, 0) = 2$.

Contd P/2

MATH 323/CHE

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) Find a PDE arising from $\phi(x - y + z, x^2 + 2y^2 - 3z^2) = 0$ **(10)**

   (b) Using Lagrange's method solve the PDE $pz - qz = z^2 + (x + y)^2$ **(10)**

   (c) Find the complete and singular integrals of $z^2(p^2z^2 + q^2) = 1$ **(15)**

6. (a) Using Charpit's method find the solution of the PDE $p(q^2 + 1) + (b - z)q = 0$ **(15)**

   (b) Solve the following PDE:

   (i) $\left(D_x^3 - 4D_x^2D_y + 5D_xD_y^2 - 2D_y^3\right)z = (y + x)^{1/2}$ **(10)**

   (ii) $x^2D_x^2 - y^2D_y^2 = x^2y$ **(10)**

7. (a) Write down the Laplace's equation $\nabla^2 u(x, y, z) = 0$ in spherical polar coordinates (r, θ, ϕ) and hence solve this equation considering various cases. **(18)**

   (b) Find the steady temperature inside a solid sphere of unit radius if one hemisphere of its surface is kept at temperature zero and the other at temperature unity. **(17)**

8. (a) If the potential is a constant v_0 on the spherical surface of radius R, show that $v = v_0$ at all interior points, and $v = \frac{v_0 R}{r}$ at each exterior point. **(18)**

   (b) A long rectangular plate of width one centimeter with insulated surfaces has its temperature $v(x, y)$ equal to zero on both the long sides and one of the short sides so that $v(0, y) = v(\pi, y) = v(x, \infty) = 0$, $v(x, 0) = \lambda x$. Determine the steady-state temperature within the plate. **(17)**
